Field-based Simplified Approach of Evaluating Knee Extensor Muscle Strength and Size in Male University Freshmen

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Abstract: The purpose of this study was to examine the relationship between field-based simplified approaches and knee extensor muscle strength/size in young men. Knee extensor muscle thickness (MT) of 104 healthy university freshmen was measured at the anterior half of thigh length; maximal voluntary isometric contraction (MVIC) was measured when subjects performed knee extension. Field-based simplified approaches [sit-to-stand, standing long jump (SLJ), handgrip and upper-leg-50% (thigh) girth] were also measured. MVIC was correlated with SLJ (r = 0.361, $P < 0.001$), handgrip (r = 0.523, $P < 0.001$) and thigh girth (r = 0.401, $P < 0.001$), but not with the sit-to-stand test (r = 0.126, $P > 0.05$). MT was correlated with handgrip (r = 0.317, $P < 0.001$) and thigh girth (r = 0.632, $P < 0.001$), but not with SLJ (r = 0.038, $P > 0.05$) or the sit-to-stand test (r = 0.145, $P > 0.05$). A stepwise multiple-regression analysis was applied to the predictor thigh girth to predict knee extensor MT ($R^2 = 0.399$). To predict knee extensor MVIC, the predictor handgrip, thigh girth and SLJ were applied ($R^2 = 0.381$). In conclusion, knee extensor muscle strength/size could be evaluated by the field-based simplified approaches, in particular by the thigh girth measurement, which may be major determinant to maintain activities of daily living for healthy young men. However, the 4 field-based simplified approaches appear to be still not of high impact.

Key words: Physical fitness test, standing broad jump, chair stand, knee extension, muscle thickness.

1. Introduction

Maintaining lower limb muscle strength and size are important in preventing and delaying the onset of disability, physical frailty, and dependency [1-3]. In general, it is well known that the loss of skeletal muscle strength and size with increased age (sarcopenia) is greater in the lower limbs than in the upper limbs (18-88 years [4]; 20-89 years [5]). In addition, recent studies revealed that the sarcopenia is muscle specific and that greater knee extensor muscle loss was found in older adults [6-8]. Therefore, periodic assessment of knee extensor muscle strength and size is important for all ages to evaluate the functional status of individuals and to identify and

treat those at risk for mobility problems and frailty.

In periodic and field-based simplified approaches, handgrip strength measurement has been widely used in clinical practice for the assessment of muscle size or strength [9-11]. However, the handgrip strength is an objective measure of the upper limb muscle [10, 12], therefore the field-based simplified approaches for muscle size or strength should likewise be focused on the knee extensor muscles for lower limb muscle assessment. To date, the strength, size, or power for lower body/limb muscles has been frequently evaluated by the use of upper-leg girth measurement [13, 14], sit-to-stand test [15-17], or standing long jump measurement [18, 19], because these measurements are also affordable, portable, simple and time-efficient. However, it is unknown whether

these field-based simplified approaches correspond to evaluation in knee extensor muscle strength or size. Thus, the purpose of this study was to examine the relationship between field-based simplified approaches and knee extensor muscle strength or size in young men.

2. Method

2.1 Participants

A total of 116 Japanese university freshmen (aged 18-20 years) were recruited in a "Sports Practice" course at the Faculty of Science and Engineering in our university. Before informed consent was obtained, a written description of the purpose of the study and its safety was distributed to potential subjects, along with a lifestyle questionnaire. All subjects were free of overt chronic disease (e.g., diabetes, angina, myocardial infarction, cancer, and stroke) as assessed by self-report. In addition, musculoskeletal disease or knee joint surgery were also excluded in this study. As a result, 104 male university freshmen were used for data analyses. The study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee for Human Experiments of the academic institute.

2.2 Muscle Thickness and Girth Measurement

Abe et al. [20] revealed that muscle thickness (MT) at the anterior thigh is strongly correlated with anatomical muscle cross-sectional area for knee extensor muscles ($n = 52$, r = 0.91, $P < 0.001$). Therefore, MT was measured using B-mode ultrasound (Voluson i, GE Healthcare, Milwaukee, WI, USA) at anterior upper leg (at 50% between the lateral condyle of the femur and the greater trochanter) on the right side of the body [21, 22]. After thigh length measurements using anatomic landmarks described earlier, all measurement sites were marked with a marker pen and then mid-thigh girth (at 50% of thigh length) was measured using a tape measure. The measurement for MT was taken while the subjects

stood quietly with their knees extended and relaxed. A linear transducer with a 3-8 MHz scanning head was coated with water-soluble transmission gel to facilitate acoustic contact and reduce pressure from the scanning head to achieve a clear image. The scanning head was placed on the skin surface of the measurement site using the minimum pressure required. The subcutaneous adipose tissue–muscle interface and muscle-bone interface were identified from the ultrasonic image, and the distance between the 2 interfaces was recorded as MT. Two images from the same site were stored, and the mean value was used for data analysis. The coefficient of variation (CV) of MT measurement from test-retest was 1.3%. The same investigator made all of the ultrasound measurements.

2.3 Maximal Voluntary Isometric Contraction Measurement

Maximum voluntary isometric contraction (MVIC) of the knee extensors was determined using a knee extension dynamometer (T.K.K. 5715, TAKEI Scientific Instruments Co., Ltd., Tokyo, Japan). The subjects were seated on a chair with their hip joint angle positioned at approximately 85 ° (full extension: 0 °). The ankle of the right leg was firmly attached to the strain gauge transducer with a chain strap (T.K.K. 5710e, TAKEI Scientific Instruments Co., Ltd.). After a warm-up consisting of submaximal contractions, the subjects were instructed to perform MVIC knee extension at a knee joint angle of approximately 90 °. Each subject was given 2 trials with an interval of at least 3 min between trials. The highest score was adopted for the individual data. The CV of MVIC measurement from test-retest was 7.6%.

2.4 Handgrip Strength Test

Handgrip strength was measured using a factory-calibrated hand dynamometer (T.K.K. 5401, TAKEI Scientific Instruments Co., Ltd.). All subjects were instructed to maintain an upright standing

position, arms at their side, holding the dynamometer in the right hand with the elbow extended at 180 ° without squeezing the arm against the body. The size of the dynamometer's handle was set to that which felt comfortable to the subject while squeezing the grip. Each subject underwent 2 trials, and the best value of the trials was used for analysis. The CV of handgrip strength measurement from test-retest was 3.1%.

2.5 Standing Long Jump Test

All subjects were instructed to perform a long jump from a standing position. Standardized instructions were given to subjects that permitted them to begin the jump with bent knees and swing their arms to assist in the jump [19]. The length of 3-m hard surface mat (starting and 10 cm interval lines drawn) (TOEILIGHT, Touyoutaiki Co., Ltd., Kyoto, Japan) was used. The length of jump was determined using drawn lines and a tape measure. Each subject performed 2 trials, and the distance of the best jump was measured, to the nearest 1 cm, from the line to the point where the heel closest to the starting line landed. If the subjects fell backward, the distance where the body part closest to the starting line touched the ground was measured as the jump's length. The longest jump score was adopted for the individual data [19]. The CV of standing long jump measurement from test-retest was 3.1%.

2.6 Sit-to-Stand Test

A wooden molded chair (0.40 m height and 0.30 m depth) was used for the sit-to-stand test. The subjects were asked to stand up from a sitting position and then to sit down during 30 seconds as many times as possible. The subjects were instructed to stand up fully and to place their buttocks on the chair in a sitting position between repetitions [17]. The test started when the examiner said "Go" and stopped after 30 seconds [15]. Prior to the measurements, practice trials with submaximal effort were performed for positioning and learning of the task. Each subject

performed 2 trials with an interval of at least 3 min between trials. The highest repetition score was adopted for the individual data. The CV of the sit-to-stand measurement from test-retest was 6.9%.

2.7 Statistics

Results are expressed as mean ± standard deviation (SD) for all variables. Pearson product correlations of knee extensor MT or MVIC and the simplified approaches were also statistically quantified. A stepwise multiple-regression analysis was performed to predict MT or MVIC and physical characteristics (height and weight) and simplified approaches as factors. All data were analyzed using JMP v.12.0 for Mac (SAS Institute Inc., Tokyo, Japan). Statistical significance was set at $P < 0.05$. The sample size was estimated from a priori power analysis to detect the correlation using the software G*Power 3.1 (power of 0.80, an α of 0.05, two-tailed, and ρ＝0.3 [Medium effect size]) by the reference [23]. Consequently, it was determined that a minimum of 84 participants were required.

3. Results

3.1 Pearson Product Correlations

The physical characteristics and field-based simplified approaches are shown in Table 1. The correlation coefficients between knee extensor muscle strength or size and field-based simplified approaches are shown in Table 2. There were significant correlations between knee extensor MVIC and handgrip, upper-leg 50% girth and standing long jump ($P < 0.001$), but not for the sit-to-stand test ($P = 0.202$) (Table 2). There were significant correlations between knee extensor MT and handgrip ($P = 0.001$) and upper-leg 50% girth ($P = 0.001$), but not for standing long jump ($P = 0.705$) or the sit-to-stand test ($P = 0.143$) (Table 2).

3.2 A Stepwise Multiple-Regression Analysis

A stepwise multiple-regression analysis was applied

Table 1 Physical characteristics, knee extensor muscle size or strength and field-based simplified approaches in university freshmen (n = 104).

Variable	Mean (SD)	Range
Age (years)	18.2 (0.5)	18-20
Height (m)	1.71 (0.05)	1.57-1.81
Weight (kg)	62.9 (7.9)	47.0-84.3
Upper-leg length (cm)	40.2 (1.5)	37.0-44.0
Lower-leg length (cm)	39.6 (1.5)	35.0-43.0
Body mass index (kg/m^2)	21.6 (2.6)	16.3-30.0
Systolic blood pressure (mmHg)	114 (13)	78-155
Diastolic blood pressure (mmHg)	69 (10)	46-96
Knee extensor muscle size		
Anterior upper-leg MT (cm)	5.2 (0.7)	3.7-7.2
Knee extensor muscle strength		
MVIC (kg)	43.3 (12.3)	16.3-78.0
Field-based simplified approaches		
Handgrip (kg)	41.2 (6.4)	22.5-57.4
Upper-leg 50% girth (cm)	50.8 (4.3)	40.7-62.4
Standing long jump (m)	2.18 (0.21)	1.40-2.85
Sit-to-stand (reps/30-sec)	34.7 (4.7)	24-44

MT, muscle thickness; MVIC, maximal voluntary isometric contraction.

Table 2 Pearson's correlation coefficients between knee extensor muscle strength or size and field-based simplified approaches.

	Pearson's correlation	
	MVIC	MT
Field-based simplified approaches		
Handgrip	0.523**	0.317**
Upper-leg 50% girth	0.401**	0.632**
Standing long jump	0.361**	0.038
Sit-to-stand	0.126	0.145

**P < 0.01, *P < 0.05. MVIC, maximal voluntary isometric contraction; MT, muscle thickness.

to the predictor handgrip, upper-leg 50% girth and standing long jump to predict knee extensor muscle strength (knee extensor MVIC (kg) = 14.989 × standing long jump (m) + 0.858 × upper-leg 50% girth (cm) + 0.617 × handgrip (kg) – 58.659 (n = 104, R^2 = 0.381, P < 0.01). To predict knee extensor muscle thickness, the predictor upper-leg 50% girth was applied (knee extensor MT (cm) = 0.098 × upper-leg 50% girth (cm) + 0.245 (n = 104, R^2 = 0.399, P < 0.001).

4. Discussion

4.1 Major Finding

The main findings of this study were: (1) significant correlations were found between knee extensor MVIC and handgrip, upper-leg 50% girth, and standing long jump; (2) knee extensor MT was significantly correlated to upper-leg 50% girth; and (3) a stepwise multiple-regression analysis could be applied to the predictor only upper-leg-50% girth to predict both knee extensor MVIC and MT in young men.

4.2 Handgrip Strength Test

Unlike knee extensor muscle size, a stepwise multiple-regression analysis was applied to the predictor handgrip strength to predict knee extensor muscle strength. A previous study [24] has demonstrated that skeletal muscle size was poorly reflected by the handgrip strength in young men. On

the other hand, the handgrip strength is closely correlated to knee extensor muscle strength, regardless of age [25, 26]. These findings suggest that the handgrip strength test may be particularly beneficial for evaluating the knee extensor muscle strength regardless of age.

4.3 Upper-Leg 50% Girth Measurement

Our findings showed that upper-leg 50% girth was a major contributing factor to knee extensor muscle strength or size in young men. Previously, some studies have reported that upper-leg 50% girth was not correlated with knee extensor muscle strength or size, therefore these should not be used as indicators [27, 28]. This discrepancy might result from the different gender used in the previous studies compared to our study. Previous studies have demonstrated that there was great variability in subcutaneous fat among women compared with men [29, 30]. All subjects in the present study were men, while the previous studies had included both men and women (healthy subjects or patients) [27, 28]. Consequently, our results suggested that upper-leg 50% girth measurement rather than handgrip strength test was a useful method for evaluating both knee extensor muscle strength and size in healthy young men.

4.4 Standing Long Jump Test

In this study, a stepwise multiple-regression analysis was applied to the predictor standing long jump to predict knee extensor muscle strength but not muscle size. In contrast, a previous study reported that the standing long jump was related to leg press but not to knee extensor muscle strength [31]. Furthermore, a linked-segment analysis and inverse dynamics methods study [18] demonstrated that the contributions of hip, knee, and ankle muscles were 45.9%, 3.9%, and 50.2%, respectively, for the standing long jump. Although the standing long jump test is an indicator of muscle power of the lower body [18, 19], it is difficult for older adults or for knee joint

pain patients to perform due to the extreme pressure on the knee joint. Taken together, it appears that the standing long jump is limited to the evaluation of knee extensor muscle strength only for healthy young men.

4.5 Sit-to-Stand Test

A sit-to-stand test can be a convenient measurement for assessment of the age-related decline in the knee extensor muscle strength but not in the muscle size for older adults [15, 17]. In this study, however, there was no significant correlation between the sit-to-stand test and knee extensor muscle strength or size in young men. The CV was lower in this study (13.7% for young men) than in previous studies (26.0% for older adults [15], 19.2%-41.8% for older adults [17]), indicating that there was great variability in the sit-to-stand test capability among studies (young vs. older adults). Thus, the sit-to-stand test provides a reasonably reliable and valid indicator of knee extensor muscle strength in older adults, but not in young adults.

5. Limitations

Some limitations of this study should be discussed. First, as the subjects were Japanese university freshmen, the age distribution and the physical characteristics were very limited. Second, our samples comprised only men, therefore we cannot infer similar results for women. Additional research is needed to address these issues.

6. Conclusion

Our results indicated that knee extensor muscle strength/size could be evaluated by the field-based simplified approaches, especially for the upper-leg 50% girth measurement, which may be major determinant to maintain an active life for healthy young men. However, the 4 field-based simplified approaches appear to be still not of high impact.

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